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Accuracy of self-reported pesticide use duration information from licensed pesticide applicators in the Agricultural Health Study

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Epidemiologists frequently rely on self-reported information regarding a variety of exposures including smoking history, medication use, and occupational exposure because other sources of information are either unavailable or difficult to obtain. One way to evaluate the accuracy of self-reported information is through logic checks using other sources. To assess the quality of the self-reported pesticide product use history of 57,311 licensed pesticide applicators in the Agricultural Health Study (AHS), we compared the self-reported decade of first use and total years of use to the year the pesticide active ingredient was first registered for use. We obtained pesticide active ingredient registration information from the United States Environmental Protection Agency (USEPA) and other publicly available sources for the 52 pesticides on the AHS initial questionnaires administered from 1994 to 1997. Based on the registration year, we assessed 19 pesticides for potential inaccuracies regarding duration of use or decade of first use. When calculating potential total years of use, we did not consider the impact of chemicals being removed from the market, since the possibility for continued use existed. The majority of respondents provided plausible responses for both decade of first use and total duration of use. On average, 1% of the subjects overestimated total possible duration of use, ranging from less than 1% for carbofuran and chlorpyrifos to 5% for imazethapyr. Decade of first use was also reasonably reported, although more subjects did not report decade of first use than duration of use, with an average of 6% of subjects missing decade information for an individual chemical. For subjects who reported a decade of first use, 98% gave plausible responses on average, with overestimates highest for cyanazine, introduced in 1971 (6% reported earlier use), and chlorimuron ethyl, introduced in 1985 (7% reported earlier use). This analysis provided the opportunity to consider only one source of potential overreporting of exposure, and while underreporting may have also occurred, we cannot evaluate its role nor the balance between these potential inaccuracies. While we are unable to validate directly the accuracy of a respondent's use of pesticides, this analysis suggests that participants provide plausible information regarding their pesticide use.
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Introduction

Self-reported information on a wide variety of exposures, such as medication use, diet, smoking, and occupational history, is a critical component of most epidemiologic studies. This information is used not only to define exposed and unexposed subjects but also to estimate duration of exposure. Frequently, there is no external source from which to obtain objective exposure data.

Pesticide exposure history among farmers and other pesticide applicators is obtained almost exclusively *via* self-report. Farmers are self-employed and there are limited alternate sources of information regarding their personal exposure to pesticides. Other investigators have used pesticide supplier reports (Blair and Zahm, 1993) and self-reported pesticide use information provided earlier (Engel et al., 2001) to assess the validity of retrospectively reported pesticide use data. The reliability of farmers self-reported data has been assessed among Iowa farmers through repeated measurement with the same instrument (Blair et al., 2002). These studies have indicated that farmers provide reproducible data regarding which pesticide products they use. However, little investigation has been done regarding the accuracy of self-reported information, particularly with regard to duration of exposure. To evaluate the plausibility of self-reported pesticide use among licensed pesticide applicators in the Agricultural Health Study (AHS), we used information regarding year of pesticide active ingredient registration as a lower bound for year of first use. In addition to evaluating the quality of self-reported information, we describe the process to obtain pesticide active ingredient

1. Abbreviations: AHS, Agricultural Health Study; PPIS, Pesticide Product Information System; RED, Reregistration Eligibility Decision; USEPA, United States Environmental Protection Agency

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registration information for the pesticide products included on the AHS questionnaire.

Methods

The AHS is a cohort of 57,311 certified pesticide applicators and spouses of some of these applicators in Iowa and North Carolina (Alavanja et al., 1996). Participants enrolled at pesticide certification classes in 1994–1997 by completing a self-administered questionnaire regarding their pesticide use history for 50 individual pesticides (or in some cases products used in combination) with detailed information regarding duration of use and decade of first use collected for 22 pesticides. An additional take-home questionnaire that obtained detailed information on the remaining 28 pesticides was completed by ~40% of the cohort. The questionnaire included a few pesticide combinations (maneb and mancozeb, carbon disulfide and carbon tetrachloride, and permethrin and other pyrethroids), resulting in 52 distinct pesticide active ingredients. Responses from participants who did and did not complete the take-home questionnaire were similar with regard to pesticide use practices (Tarone et al., 1997).

Pesticide applicators were asked about their pesticide use history on a chemical-specific basis. For each pesticide, they were asked the following: "Have you ever personally mixed or applied this pesticide?" "How many years did you personally mix or apply this *pesticide*?" "In an average year when you personally used this *pesticide*, how many days did you do it?" "When did you first personally use this *pesticide*?" Pesticides were described both by the common chemical name and trade name to facilitate recognition by respondents (e.g., Sevin, Carbamine, or other carbaryl products). Participants were given categories from which to select the appropriate response. Figure 1 presents the question structure. Copies of the questionnaires are available on the AHS website (www.aghealth.org).

To evaluate the accuracy of the self-reported information, we obtained the dates of first pesticide active ingredient registration in the US for the 52 pesticides. This registration information, while publicly available, can be difficult to obtain due to the large number of products on the market that contain the same pesticide and changes in record-keeping requirements over time. Two basic approaches were employed for determining the dates of initial registration. The first approach (Approach 1) consisted of searching a wide variety of electronic sources for documents containing information on the regulatory history of one or more pesticide active ingredients. The second approach involved searching United States Environmental Protection Agency's (USEPA) Pesticide Product Information System (PPIS) (USEPA, 2001c), a database containing information on all the individual pesticide products registered in the US. In identifying registration dates, only documents from governmental agencies were used.

Name of Pesticide	Have you ever personally mixed or applied this pesticide?	How many years did you personally mix or apply this pesticide?*	In an average year when you personally used this pesticide, how many days did you do it?**	When did you first personally use this pesticide?
Pesticide	☐ No ☐ Yes	☐ 1 year or less ☐ 2-5 years ☐ 6-10 years ☐ 11-20 years ☐ 21-30 years* ☐ More than 30 years	☐ Less than 5 days ☐ 5-9 days ☐ 10-19 days ☐ 20-39 days ☐ 40-59 days ☐ 60-150 days ☐ More than 150 days	☐ Before 1960 ☐ In the 1960s ☐ In the 1970s ☐ In the 1980s ☐ In the 1990s

Figure 1. Pesticide use question format, AHS applicator questionnaires, 1994–1997. *The categories for this question were reduced on the take-home questionnaire with a maximum category of more than 20 years. **These frequency categories were used for herbicides and insecticides; the categories for fungicides and fumigants included smaller intervals.

For Approach 1, the USEPA's Office of Pesticide Programs website (USEPA, 2001b) provided documents on about half of the pesticides in the AHS questionnaires. The most useful type of document was the Reregistration Eligibility Decision (RED). These documents provided the results of USEPA's regulatory reviews of pesticides initially registered before November 1, 1984. Most of the REDs contain a regulatory history including the date of initial registration. Of the 52 pesticides investigated, EPA had completed REDs for 17 as of July 2001. Of these 17 REDs, 16 included the date of initial registration. In addition to REDs, preliminary risk assessments were prepared by USEPA for inclusion as chapters in forthcoming REDs for eight pesticides; the date of initial registration was reported for four of these eight pesticides.

The USEPA conducts Special Reviews for selected pesticides. These reviews begin with a position document published in the Federal Register and these often include a regulatory history section (USFR, 2001). The USEPA undertook Special Reviews for 26 of the questionnaire pesticides; documents associated with Special Reviews provided registration date information for 6 of 26 pesticides. Other federal sources including pesticide fact sheets on the USEPA website (USEPA, 2001a) and the National Agricultural Pesticide Impact Assessment Program (NAPIPAP, 2001) provided additional registration date information. In all, Approach 1 yielded dates of initial registration for 28 of 52 pesticides.

The limitations of the first approach necessitated the second. USEPA's PPIS (USEPA, 2001c) is a database containing information on all the individual pesticide products ever registered in the US. This database stores information individually by pesticide product, not by active ingredient; so for active ingredients that were widely used or that had multiple formulations, there was often an extensive number of products. Although the record for each pesticide product included fields for the active chemical ingredients, there were some data gaps in these fields that rendered searches by chemical ingredient alone incomplete. To

determine the date of initial registration of a specific active ingredient, we searched the database for all the products containing that ingredient and determined which of those products was registered earliest. Therefore, the following search strategy was employed for each pesticide investigated in the PPIS: (1) a search on the active ingredient and (2) a search on product name using only the common chemical name(s) of the active ingredient that was unlikely to be associated with any other chemical ingredient (such as glyphosate or captan). This strategy sacrificed sensitivity for greater specificity — some products that actually contain the ingredient may be rejected because there was no way to be certain that they do, but it was very unlikely that products that actually do *not* contain the ingredient would mistakenly be included. This second approach was employed for the 24 pesticides for which the first approach failed.

With the pesticide registration information, we were able to assess the plausibility of the participant's responses to two questions related to pesticide use: duration of use and decade of first use. We only evaluated potential overestimation of exposure based on the year of first registration since individuals may continue to use the pesticide once it has been removed from the market and we had limited resolution to evaluate potential inaccuracies for historically used chemicals. We examined three types of potentially incorrect responses from participants: (1) the total duration of use exceeded the years the pesticide was available; (2) the reported decade of first use occurred before the pesticide was introduced; and (3) the reported decade of first use was incompatible with the reported duration information. We calculated potential total years of use for all subjects by subtracting the year of registration from the year of enrollment. Using this information, we calculated the number and percent of subjects applying the pesticide who provided implausible pesticide use information. Since participants who were uncertain may have opted not to respond rather than report wrong information, we tabulated the number of applicators with missing data regarding pesticide use duration and decade of first use.

Of the 52 chemicals on the questionnaires, 21 were introduced after 1960 and therefore eligible for evaluation here. Two of these mancozeb and permethrin could not be evaluated because they were asked in combination with other chemicals that were introduced prior to 1960; thus, 19 chemicals were considered for potential inaccuracies in reporting. Only those chemicals introduced since 1960 were included because this was the earliest date on the questionnaire.

Results

Pesticide active ingredient registration information was obtained for the 52 chemicals included on the initial AHS questionnaires (Table 1). To compare the accuracy of both approaches for registration information, we obtained initial registration information for 23 chemicals using both

Table 1. US Registration year for the 52 pesticides included on the AHS enrollment questionnaires.

Common name	Date first registered in US[a]
2,4,5-T	1948
2,4,5-TP (Silvex)	1956
2,4-D	1948
Alachlor	1969
Aldicarb	1970
Aldrin	1950
Aluminum phosphide	1958
Atrazine	1959
Benomyl	1969
Butylate	1967
Captan	1951
Carbaryl	1947
Carbofuran	1969
Carbon disulfide	1947
Carbon tetrachloride	1948
Chlordane	1948
Chlorimuron ethyl	1985
Chlorothalonil	1966
Chlorpyrifos	1965
Coumaphos	1958
Cyanazine	1971
DDT	1948
Diazinon	1948
Dicamba	1956
Dichlorvos	1948
Dieldrin	1951
EPTC	1958
Ethylene dibromide	1948
Fonofos	1967
Glyphosate	1974
Heptachlor	1952
Imazethapyr	1989
Lindane	1947
Malathion	1955
Mancozeb	1962
Maneb	1952
Metalaxyl	1979
Methyl bromide	1947
Metolachlor	1976
Metribuzin	1972
Paraquat dichloride	1964
Parathion (methyl)	1954
Pendimethalin	1974
Petroleum oil herbicide[b]	1947
Permethrin	1977
Phorate	1959
Pyrethrins and pyrethroids	1950
Terbufos	1974
Toxaphene	1948
Trichlorfon	1954
Trifluralin	1963
Ziram	1948

[a]See Methods section for source information.
[b]Petroleum oil was first approved in 1924 for wood treatment and then no further registration until 1947.

Table 2. Accuracy of self-reported pesticide duration history for 19 chemicals on the AHS questionnaires.

	Percent of applicators using pesticide	Duration of use information				Decade of first use information			
		Users who did not report		Users with inaccurate responses[a]		Users who did not report		Users with inaccurate responses[b]	
		n	%	*n*	%	*n*	%	*n*	%
Enrollment questionnaire (n=57,311)									
Alachlor	47	314	1	155	1	1295	5	206	1
Carbofuran	23	175	1	15	0	521	4	80	1
Chlorothalonil	8	168	4	13	0	511	12	32	1
Chlorpyrifos	38	234	1	12	0	1294	6	53	0
Cyanazine	37	231	1	74	0	882	4	1308	6
Fonofos	19	138	1	15	0	440	4	35	0
Glyphosate	70	407	1	240	1	2868	7	650	2
Imazethapyr	38	199	1	1026	5	1460	7	423	2
Metolachlor	42	237	1	619	3	1378	6	568	3
Terbufos	33	214	1	135	1	938	5	535	3
Trifluralin	47	295	1	0	–	1302	5	287	1
Take-home questionnaire (n=22,903)									
Aldicarb	8	30	2	NA[c]	–	122	7	66	4
Benomyl	8	56	3	NA	–	122	7	44	3
Butylate	25	61	1	NA	–	122	2	28	0
Chlorimuron ethyl	31	65	1	285	4	513	7	464	7
Metalaxyl	20	137	3	37	1	356	8	112	3
Metribuzin	35	70	1	NA	–	259	3	377	5
Paraquat dichloride	16	65	2	NA	–	175	5	45	1
Pendimethalin	36	94	1	26	0	515	6	156	2

[a]Inaccurate responses for duration were those with total years that exceeded number of years since first registered.
[b]Inaccurate responses for decade of first use were those that indicated using the pesticide before it was registered.
[c]NA=not applicable. The maximum duration option of >20 years on the take-home questionnaire was a correct response. There were no implausible responses likely for these chemicals.

strategies. For 10 of these chemicals, more than one initial registration year was identified; for two of these, there was a greater than 2-year difference. These were coumaphos (1958 or 1964) and petroleum oil herbicide (first registered use in 1924 as a wood treatment and the next registered use in 1947). In all cases, we used the earliest year to estimate accuracy of the self-reported information.

The completeness and plausibility of the self-reported information were excellent for the 19 pesticides evaluated (Table 2). A majority of the applicators who used a pesticide reported a duration of use (96–99% of users, mean=99%) and a decade of first use (88–96% of users, mean=94%). For those subjects who reported duration of use, the potentially overestimated responses ranged from less than 1% for most of the pesticides to 5% for imazethapyr. Decade of first use information was missing for more subjects than duration of use, with an average of 6% of users failing to report the decade of first use for a particular chemical. Among those reporting decade of first use, the data were of high plausibility, with only 0–7% of chemical users reporting using the chemical prior to its introduction on the market. Six percent of cyanazine users who provided a decade of first use reported using this chemical prior to 1970; however, our data searches indicated that this chemical was introduced in 1971. In spite of the erroneous report by 6% of cyanazine users, less than 1% of cyanazine users provided implausible responses with regard to their reported total duration of exposure. The extent of incompatible self-reported information between duration of use and decade of first use was not significantly different than the individual results for duration and decade and are not presented. When we restricted the analyses to farmers over age 50 — the population most likely to overreport exposure since they have been applying chemicals for more than 30 years — the results for overestimation of duration of exposure were similar to those for the whole cohort, while reporting of decade of first use prior to introduction of the chemical was slightly higher (data not shown). Accuracy of reporting did not appear related to prevalence of use (Table 2).

Discussion

Farmers provide reliable and reproducible information regarding their pesticide application history (Blair and Zahm, 1993; Blair et al., 2002; Engel et al., 2001). Blair and Zahm (1993) reported 60% agreement between pesticide

applicators and suppliers, which may be regarded as an underestimate since suppliers may have less information regarding an applicator's use. In a 1997 follow-up study of orchardists, the sensitivity for pesticide use in 1972–1976 was moderate to high (0.5–0.9) for commonly used pesticides and, for most pesticides, did not differ by subject age (Engel et al., 2001). Among the Iowa participants of the AHS, Blair et al. (2002) reported higher reliability for ever use of a particular pesticide (70–90%) than for duration of use (50–60%), although both measures were very reliable and did not differ within the population from 1 year to the next. As illustrated here, AHS farmers also provide plausible responses regarding their duration of specific pesticide use. The percent of incomplete or implausible responses by the certified pesticide applicators in the AHS cohort was extremely low, on average, less than 2%. Thus, the impact of overestimation of exposure by our subjects is anticipated to be minimal. In this analysis, we were only able to evaluate overestimation based on questionnaire categories and some subjects may be overreporting their actual exposure; however, there are no data to assess this. Underreporting may also have occurred and it is unclear where the balance between overreporting and underreporting lies.

Information regarding year of pesticide registration is particularly difficult to obtain but, once obtained, is a useful means to evaluate potential pesticide exposure. Through USEPA and other governmental sources, we were able to obtain information regarding pesticide active ingredient registration for 52 commonly used pesticides in the US. We were able to evaluate the plausibility of participants' responses regarding total duration of pesticide use and decade of first use. In the future, this information could be used to correct implausible responses by assigning the correct maximum value, and thus preventing overestimation of exposure, which would lead to an attenuation of dose–response curves due to misclassification of the highest category. Fortunately, in our data, few individuals overestimated their exposure so the impact of this is unlikely to bias future analyses.

Evaluation of last year of use is not possible in our data for a number of reasons. Pesticide use can continue after a product is removed from the market. Often, pesticide use regulations change and prohibit use for one crop or type of application, but still allow other uses to occur. We do not have information regarding crop-specific uses of pesticides from the questionnaire. And, thus, we cannot evaluate changes in use as a result of changing pesticide registration and can only consider lifetime pesticide use. Finally, most of the chemicals with recent registration information are still currently in use and the older ones that are no longer in use had no possibility for overestimation using our questionnaire because we included 1960 as the earliest decade. For chemicals that have been removed from the market, such as DDT, we lack appropriate resolution in our questionnaire to determine if the duration responses are consistent with legal use of these products, since most of these chemicals were on the market for more than 30 years (our questionnaire maximum value).

The AHS cohort consists of certified pesticide applicators and their spouses. As certified pesticide applicators, these subjects are trained with regard to pesticide regulations and are responsible for the purchase and application of chemicals on their farm. This involvement with pesticide selection and use makes farmers a unique occupationally exposed population and suggests why studies of farmers' self-reports indicate the ability to provide high-quality data regarding pesticide exposure. The high degree of accuracy suggested among our cohort was probably a combination of good recall of pesticide use and the broad categories of exposure used to assign duration. The chemicals with the highest rate of implausible information were those chemicals that were introduced near a year that was a cutpoint for the questionnaire category. For example, cyanazine was introduced in 1971 and 6% of subjects who used the chemical reported first using this chemical prior to 1970. While we are unable to validate directly the accuracy of a respondent's use of pesticides, this analysis suggests that participants provide plausible information regarding their pesticide use.

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References

Alavanja M.C., Sandler D.P., McMaster S.B., Zahm S.H., McDonnell C.J., Lynch C.F., Pennybacker M., Rothman N., Dosemeci M., Bond A.E., and Blair A. The Agricultural Health Study. *Environ Health Perspect* 1996: 104: 362–369.

Blair A., and Zahm S.H. Patterns of pesticide use among farmers: implications for epidemiologic research. *Epidemiology* 1993: 4: 55–62.

Blair A., Tarone R.E., Sandler D., Lynch C.F., Rowland A., Wintersteen W., Steen W.C., Samanic C., Dosemeci M., and Alavanja M.C.R. Reliability of reporting on lifestyle and agricultural factors by a sample of participants in the Agricultural Health Study from Iowa. *Epidemiology* 2002: 13: 94–99.

Engel L.S., Seixas N.S., Keifer M.C., Longstreth W.T. Jr., and Checkoway H. Validity study of self-reported pesticide exposure

among orchardists. *J Expos Anal Environ Epidemiol* 2001: 11: 359–368.

National Agricultural Pesticide Impact Assessment Program (NAPIPAP). *National Agricultural Pesticide Impact Assessment Program website,* ipmwww.ncsu.edu/opmppiap. 2001.

Tarone R.E., Alavanja M.C., Zahm S.H., Lubin J.H., Sandler D.P., McMaster S.B., Rothman N., and Blair A. The Agricultural Health Study: factors affecting completion and return of self-administered questionnaires in a large prospective cohort study of pesticide applicators. *Am J Ind Med* 1997: 31: 233–242.

United States Environmental Protection Agency (USEPA). *USEPA Index of Pesticide Factsheets,* www.epa.gov/pesticides/factsheets/. 2001a.

United States Environmental Protection Agency (USEPA). *USEPA Office of Pesticide Programs home page,* www.epa.gov/pesticides/. 2001b.

United States Environmental Protection Agency (USEPA). *USEPA's Pesticide Product Information System (PPIS),* www.epa.gov/opppmsd1/PPISdata/index.html. 2001c.

United States Federal Register (USFR). *US Federal Register online,* http://www.access.gpo.gov/su_docs/aces/aces140.html. 2001.